General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

JSC-11652

CR-151136

TECHNICAL MEMORANDUM

REMOTE SENSING FOR CONTROL OF TSETSE FLIES

Job Order 92-105

(NASA-CR-151136) REMOTE SENSING FOR CONTROL OF TSETSE FLIES (Lockheed Electronics Co.) 38 p HC A03/MF A01 CSCL 06F

N77-13491

Unclas

G3/43 57920

Prepared By

Life Sciences Applications Department

Lockheed Electronics Company, Inc.

Aerospace Systems Division

Houston, Texas

Contract NAS 9-12200

For

HEALTH APPLICATIONS OFFICE

LIFE SCIENCES DIRECTORATE

DEC 1976
RECEIVED
NASA STI FACILITY
INPUT BRANCH

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

September 1976

LEC-9155

Contract NAS 9-12200
Job Order 92-105
JSC-11652

TECHNICAL MEMORANDUM

REMOTE SENSING FOR CONTROL OF TSETSE FLIES

PREPARED BY

L. E. Giddings

A. Naumann, Program Manager
NAS 9-12200

Prepared By

Lockheed Electronics Company, Inc.

For

Bioengineering Systems Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

September 1976

LEC-9155

TECHNICAL REPORT INDEX/ABSTRACT

(See instructions on reverse side.)

1. TITLE AND SUBTITLE OF DOCUMENT Technical Memorandum Remote Sensing for Control of Tsetse Flies	2. JSC NO. JSC-11652
3. CONTRACTOR/ORGANIZATION NAME Lockheed Electronics Co., Inc.	4. CONTRACT OR GRANT NO. NAS 9-12200
5. CONTRACTOR/ORIGINATOR DOCUMENT NO. LEC 9155	6. PUBLICATION DATE (THIS ISSUE) September 1976
7. SECURITY CLASSIFICATION Unclassified	8. OPR (OFFICE OF PRIMARY RESPONSIBILITY)
9. LIMITATIONS GOVERNMENT HAS UNLIMITED RIGHTS ☐ YES ☐ NO IF NO, STATE LIMITATIONS AND AUTHORITY	10. AUTHOR(S) L. Giddings
11. DOCUMENT CONTRACT REFERENCES	12. HARDWARE CONFIGURATION
WORK BREAKDOWN STRUCTURE NO. 63-0999-2105	SYSTEM
CONTRACT EXHIBIT NO.	SUBSYSTEM
DRL NO. AND REVISION	MAJOR EQUIPMENT GROUP
DRL LINE ITEM NO.	

13. ABSTRACT

Remotely sensed information has potential for aiding in the control or eradication of tsetse flies. Data are available from earth resources meteorological, and manned satellites, from airborne sensors, and possibly from data collection platforms. A new zone discrimination technique, based on data from meteorological satellites may also allow the identification of zones hospitable to one or another species of tsetse. For background, a review is presented of the vegetation of Tanzania and Zanzibar, and illustrations presented of automatic processing of data from these areas. In addition, a review is presented of the applicability of temperature data to tsetse areas.

14. SUBJECT TERMS

CONTENTS

Section | Page

FIGURES

ABBREVIATIONS AND ACRONYMS

ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
GARP	Global Almospheric Research Program
GOES	Geostationary Operational Environmental Satellite
ITOS	Improved TIROS Operations Satellite
Landsat	Land Satellite
LARS	Laboratory for Application of Remote Sensing
LARSYS	Classification System of LARS
MSS	Multispectral Scanners
NOAA	National Oceanic and Atmospheric Administration
SEDS	Screwworm Eradication Data System
SMS	Synchronous Meterological Satellite
TIROS	Television and Infrared Observation Satellite
VHRR	Very High Resolution Radiometer

1. INTRODUCTION

The tsetse flies of Africa are strongly controlled by habitat. Each specie of epidemiological interest is quite demanding in environmental factors. To eradicate them, it is vital to know the extent of zones that are subject to infestation. Information on these zones would be of very real benefit to professionals charged with eradication of this dangerous pest.

Remote sensing can probably furnish such information. Well developed technology allows us to discriminate vegetation zones. More recent developments allow us to monitor surface temperatures. Still more advanced technology, outfall of the screwworm eradication program, allows us to discriminate ecological and botanical zones. In short, remote sensing can furnish the kind of synoptic information needed to support eradication of the tsetse fly.

It will be up to entomologists and other specialized professionals to decide the use to be made of remote sensing. This report is prepared for their guidance. It presents a review of those capabilities that appear most promising to tsetse control activities, with special emphasis on the special test sites in Tanzania. Where appropriate, it includes samples and catalogs of images.

2. SOURCES OF REMOTELY SENSED INFORMATION

There is a large variety of remotely sensed information available for support of tsetse habitat studies. This section reviews these data, with brief comments on their potential usefulness. A general review of satellites can be found in reference 1.

2.1 IMAGES FROM EARTH RESOURCES SATELLITES

The only earth resources satellites yet in orbit are ERTS-1/Landsat-1 and ERTS-2/Landsat-2 launched in 1973 and 1975. Both are functional on a direct broadcast (line-of-sight) basis. Landsat-1 is no longer available for areas not within line of sight of a receiving station; and Landsat-2 has recorder problems.

It is fortunate that some Landsat images of Tanzania were taken before failure of the tape recorders onboard, since Tanzania is not within line of sight of any receiving station.* To date, only one image allows us to see the tsetse test sites in Tanzania, reproduced in figure 1. Note this false color infrared image allows us to discriminate certain features with ease.

Future Landsat satellites will furnish even more information than Landsat-1 and -2. Landsat-3, to be launched in 1978, will furnish an additional Multispectral Scanner (MSS) channel with thermal data, and Landsat-4 will probably include one more channel and improved resolution.

The primary use of these data would be in delineating vegetation zones and communities, as demonstrated in section 3 of this report. In general, the various vegetation zones can be obtained by simultaneous study of all spectral channels from these sensors,

*Iran will construct a station in line of sight of Tanzania within a few years.

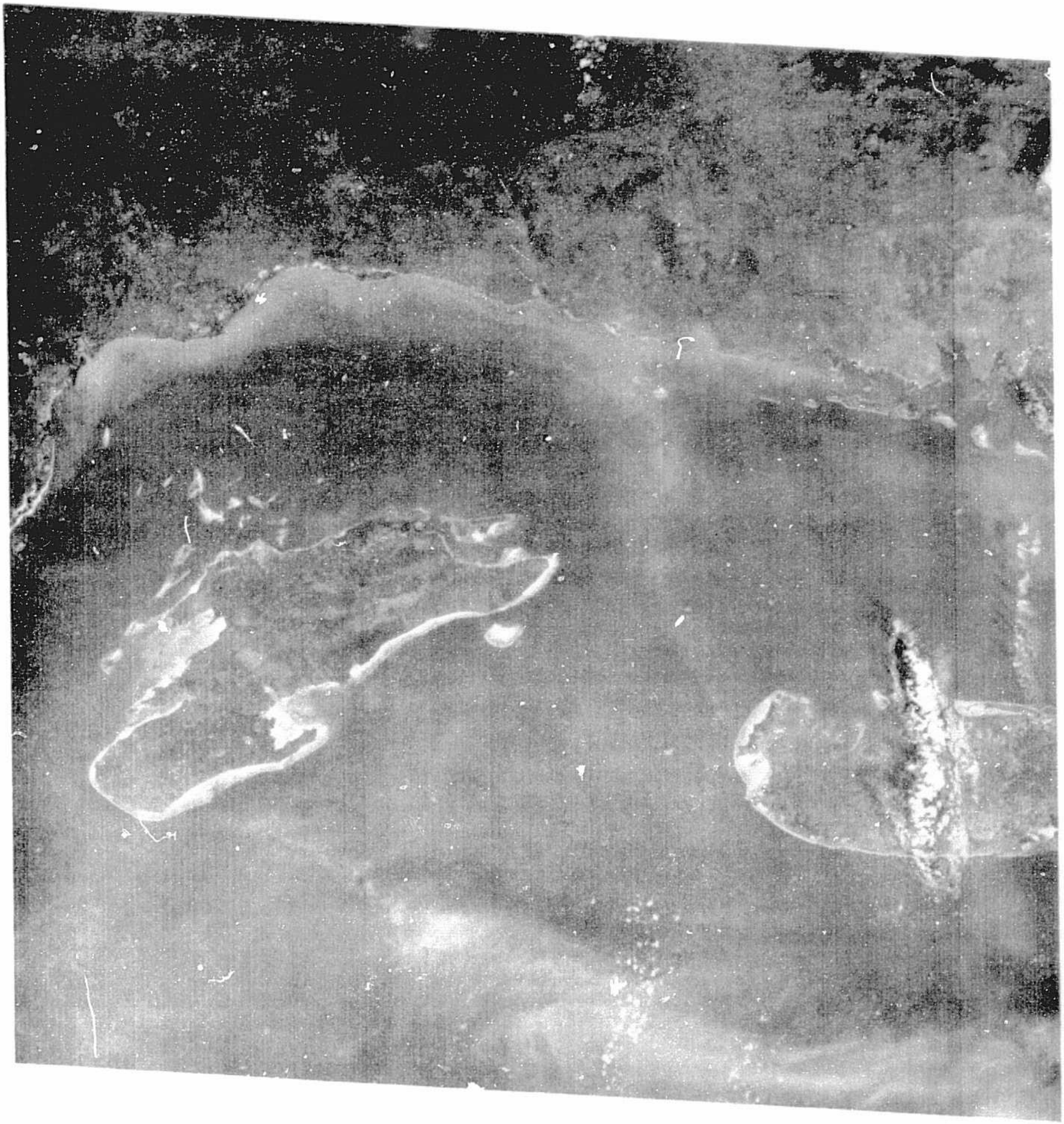


Figure 1.– Landsat image of Tanzania.

ORIGINAL PAGE IS
OF POOR QUALITY

using digital computers. By use of any set of three channels, false color photographic images can be prepared for the same purpose.

2.2 METEOROLOGICAL SATELLITES

The series of ITOS/NOAA* polar-orbiting satellites now in operation is available for immediate use of projects over the entire earth. Within two years, a new generation of polar-orbiting satellites will come into use by NOAA, and a new geosynchronous satellite will be made operational by the European Space Agency (ESA). In addition, both the Nimbus series and ATS-6 are available for special projects. These will be discussed, one by one, to show the kinds of data available from them.

The ITOS/NOAA satellites have two principal sensors, the Scanning Radiometer, with 8 kilometer resolution, and the Very High Resolution Radiometer (VHRR), with 0.8 kilometer resolution. Both broadcast continuously to anyone with an adequate receiver, but only the low resolution sensor can be received with inexpensive stations. Data from both can be recorded onboard the satellite and then retransmitted to ground stations in the United States. However, few high resolution data can be recorded in this way because of inherent limitations of the onboard recorder.

The low resolution data are available on a routine, nearly real-time basis from NOAA as photographic images. Unfortunately, they probably have no use for tsetse control.

The high resolution data are potentially useful, as will be shown later. For occasional use, they are best obtained as images on digital tapes recorded on board the satellite and later transmitted to U.S. ground stations. However, if needed on a daily basis, they would best be received from a ground station in

*Improved TIROS Operations Satellite/National Oceanic and Atmospheric Administration.

Tanzania or nearby; costs of an appropriate station would be at least $30,000 but less than $200,000 (the basic cost is low if a hand-steered antenna can be used, but high if an automatic tracking antenna is used).

The next generation of polar orbiting meteorological satellites will be available soon. The prototype, TIROS-N, is now being constructed, for launch in 1977 or 1978. The data will also be available directly to any person with an appropriate receiving station. Data will be transmitted in digital form instead of analog. They will have the same spatial resolution but will be transmitted in four spectral ranges instead of two (probably two visible and two infrared bands). They are expected to be "cleaner" (less noisy) than data from the current generation of polar orbiting meteorological satellites.

The geosynchronous satellite of the European Space Agency will be very similar to the SMS/GOES* satellites now in orbit over the Western hemisphere and Pacific Ocean. It will furnish images every half hour in visible and thermal infrared channels, with maximum spatial resolution of 2 and 8 kilometers respectively. Data will be available to all users direct from the satellite (without the "stretching" needed of SMS/GOES data). The satellite will be operational in 1978 for the first Global Atmospheric Research Program (GARP) experiment. Unfortunately, the spatial resolution may well be too low for disciminating the tsetse areas.

Some uses of these data are presented in sections 4 and 5. Composite images can be combined in a unique zone discriminator to identify ecological zones, some of which may coincide with tsetse zones. Temperature models can be used to produce detailed temperature variations throughout the tsetse areas; these can be produced as often as daily, and summations and averages can be produced for any period of time.

*Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite.

2.3 PHOTOGRAPHS FROM MANNED SPACE FLIGHTS

Because of the haziness and cloudiness of the Tanzania area, no useful pictures have been taken from any of the manned satellite missions. In all pictures from the Gemini, Apollo, and Skylab missions, an abundance of haze obscures almost all surface features. None are even useful, and certainly none can be compared with figure 1. Appendix A contains a fairly complete listing of images of Tanzania and Zanzibar.

For the future, scientists aboard NASA's Shuttle spacecraft can be primed to take photographs of any areas important for tsetse fly control when cloud cover permits. Such photographs could be available within a few weeks, at the next return to earth of the Shuttle scientists.

The manned spacecraft flight of the Shuttle should begin about 1980. Like Skylab, this spacecraft will be equipped with a large variety of sensors. Although specifications are not yet complete, it is certain to have an extremely flexible remote sensing system, with moderate and high resolution cameras and multispectral scanners. Since Shuttle flights will be regularly scheduled, scientists can depend on them for high-quality, remotely-sensed imagery for the indefinite future. These photographs are especially useful for overall understanding of an area. They provide a unique instant education on the configuration of a large area that cannot be equaled by any other medium. At a glance a person sees the relationship of water bodies to land areas, the relationship of mountains to plains, the nature of the drainage system, and the like.

Beyond this, these photographs can also furnish more detailed information on specific areas. Often the vegetation zoning can be understood from inspection of these photographs. Hydrological conditions can be documented that are otherwise difficult to

3. REMOTE SENSING OF VEGETATION

3.1 VEGETATION OF TANZANIA

The vegetation of Tanzania is typified by the overwhelming preponderance of woodland-savannah throughout the country. The vast majority of the plant communities in Tanzania merely reflect a slightly wetter or drier version of this basic theme.

True rainforests or tropical decidious forests are quite rare in Tanzania. The three main zones of true forest run from Mt. Kilimanjaro toward Zanzibar, from near Dar Es Salaam to the northern part of Lake Nyasa, and near the coast in southeast Tanzania. The forests only occur at higher elevations in the mountains. They are normally rather local and do not form any extended forest canopies.

Very extensive woodland development is to be found ranging diagonally across the country from Lake Tanzanyika southeast to the coast of southeast Tanzania and in most areas to the south of this line. The woodlands are bisected repeatedly by grasslands of various sorts throughout its distribution but the woodland biome constitutes the dominant vegetation over the entire southern and western half of the country.

Complementing the woodland development both in form, distribution, and dominance is the grassland. The grassland runs along the same diagonal line but also contains those lands to the east, the south, and along the coast to southeast Tanzania. The grasslands, then, dominate in the north, northeast and eastern portions, while the woodlands tend to dominate all those areas to the west, south and southwest of the country.

Throughout the woodland half of the country galleries of grasslands follow the major drainage systems. Throughout the grassland half of the country's extensive woodland developments

pervade the countryside. The entire country is a wide-spread mix of woodland and grassland which changes only in the relative density of each.

Swamps and marshes develop along many of the river systems. These wetland developments occur in response to the local lack of relief and poor soil drainage rather than to extensive rainfall. The relief on the plains is so small that natural dams develop. These act as shallow basins to hold water and allow the wetland development.

While Tanzania is dry seasonally and thus conducive to the savannah type development there are no true deserts in the country. There is a desert grassland in the north central portion and a second development of desert grasslands in the south central portion. In both areas conditions approximating a desert grassland develop, but nowhere is the dryness sufficient for the development of a true desert with its characteristic succulent floral development.

The island of Zanzibar has a simplified development. The western half of the island contains the wetter, populated areas covered with a dense woodland. The eastern half of the island is composed of a mixture of brushlands, grasslands, and thickets. Many coastal estuaries exhibit extensive development of mangroves with a littoral formation in sandy areas.

Tanzania exhibits a wide diversity of plant communities from tundra and permanent snow on Mt. Kilimanjaro to near desert and rainforest. Yet in terms of the vast majority of the landscape the entire country may be characterized by varying developments of woodland-savannah with occasional marshland development in low areas.

3.2 REMOTE SENSING

Successful remote sensing is dependent upon the sensor's ability to separate one class from another. Classes that produce very divergent signatures relative to one another tend to produce highly accurate classifications. The mapping of most shorelines is therefore quite simple because both water and sand produce unique, separable, and consistent signatures that cannot be confused with one another. The problem becomes more complex when one attempts to separate various classes of vegetation, because plants have a radiance response in the same approximate range.

Successful mapping of natural communities is often more dependent upon the separation of textures rather than changes in species composition in similar communities. Many of the most successful plant classifications are physiognomic classifications or ones based upon conspicuous changes in the gross morphology of the dominant vegetation. Grasslands are easily separable from forests for this reason. In many communities however, barren ground shows through the vegetation at certain times during the season. This fact is especially evident in desert areas and in regions with well defined dry seasons. Since the substrate has a significantly different radiance value, the integration of the substrate values into the plant values allows the development of a highly characteristic and separable signature for each community of a different density. Similarly, marshland and flooded areas exhibit highly characteristic radiance values by virtue of the contributions to the scene radiance by water. In both cases, the action of purely physical sources act to aid in the identification and characteristics of these communities.

The communities of East Africa are primarily woodland-savannah types under varying influence of rainy seasons and dry seasons. Typical botanical response to these kinds of influences include development of extensive marshlands or woodlands, grasslands,

etc. All exhibit bare soil, open water, etc., at some time during the year, and all have a highly characteristic texture of physiognomic type associated with the community.

Most of the vegetational types of Tanzania fall into the category of differentiable physiognomic classes. Less than 10 percent of the total vegetation falls into nonseparable forest classification. This latter forest classification is not important to work related to the tsetse fly eradication program. The majority of the vegetation of Tanzania may then be viewed as potentially easy to distinguish remotely. Initial work suggests that while the vegetation is very uniform and monotonous, significant separation can be achieved between various communities. In both the mainland and Zanzibar test sites, heavily forested areas are separable from less forested areas and various classes of woodland-savannah are perceivable. Additional littoral, mangrove, and other wetland communities appear separable. At this point, it is not possible to precisely identify each class indicated in the remote sensing analysis. The problem centers around the acquisition of adequate ground truth which is not currently available. It is also not possible to clarify the exact function this data might have on Tsetse fly eradication since the results of this work have not as yet been analyzed by field entomolgists associated with the tsetse fly research program.

3.3 SOME REPRESENTATIVE DATA PRODUCTS

The standard false color images available from the Landsat satellites are represented by figure 1. In this image, the green channel is displayed in blue, the red channel in green, and one of the near-infrared channels in red. This is the same coding as found in standard false color infrared ektachrome film. All four Landsat bands are also available in separate black and white photographic images.

The four differentiable physiognomic classes of vegetation of Tanzania are shown in figure 2. Note that less than 10 percent of the total vegetation falls into a nonseparable forest classification, the tsetse fly eradication program.

The standard Landsat photographic images are prepared from standard settings and often do not illustrate all the detail in the original data, which are achieved on digital computer tapes. Figure 3 shows the result of producing an electronically enhanced image. In the color original, many features can be seen which are not visible on standard products. Figure 3 was kindly prepared by the Earth Observations Division of NASA to demonstrate the potential of electronic enhancement.

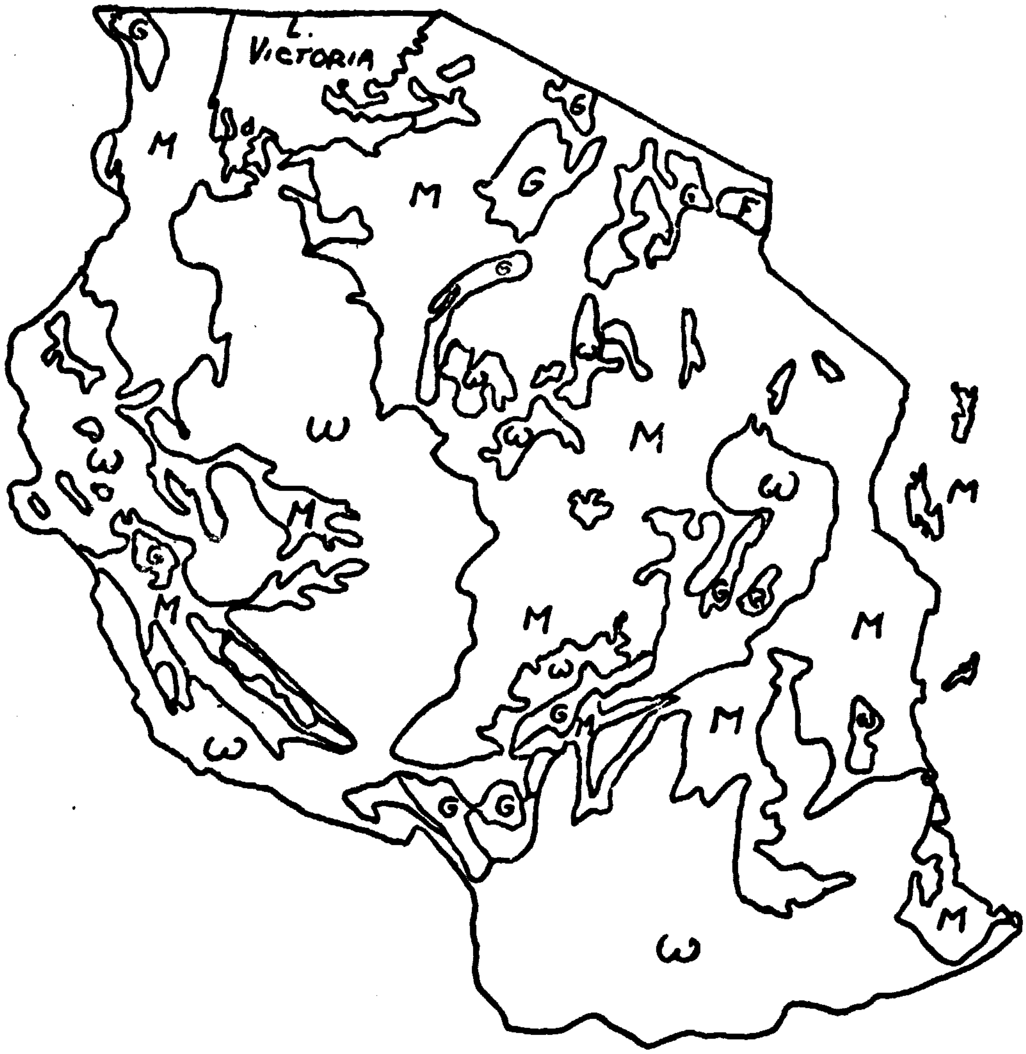
Figure 4 illustrates one form of computer classification of Landsat images. In this case, taped data were processed by standard clustering, or nonsupervised classifications procedures. Results are produced on a line printer, as shown here, or as an image product that can be displayed as a photographic image. This figure was also kindly prepared by the Earth Observations Division to illustrate the technique.

3.4 AIRBORNE SENSORS

Most remote sensors can also be mounted in aircraft; indeed, aircraft photography is the most venerable form of remote sensing.

The greater resolution obtainable from low-altitude sensors partially offsets the inherent disadvantage of higher costs, especially when only limited areas need scrutiny.

In addition to greater resolution, aircraft can function in areas that are often cloudy. They can underfly clouds, or they can fly when there are no clouds. By contrast, the Landsat satellites pass over an area once in eighteen days, always at the same time.



F = FOREST

W = WOODLAND

M = WOODED GRASSLAND

G = GRASSLAND (TRUE SAVANNA)

Figure 2.– Generalized physiognomic vegetation map of Tanzania.

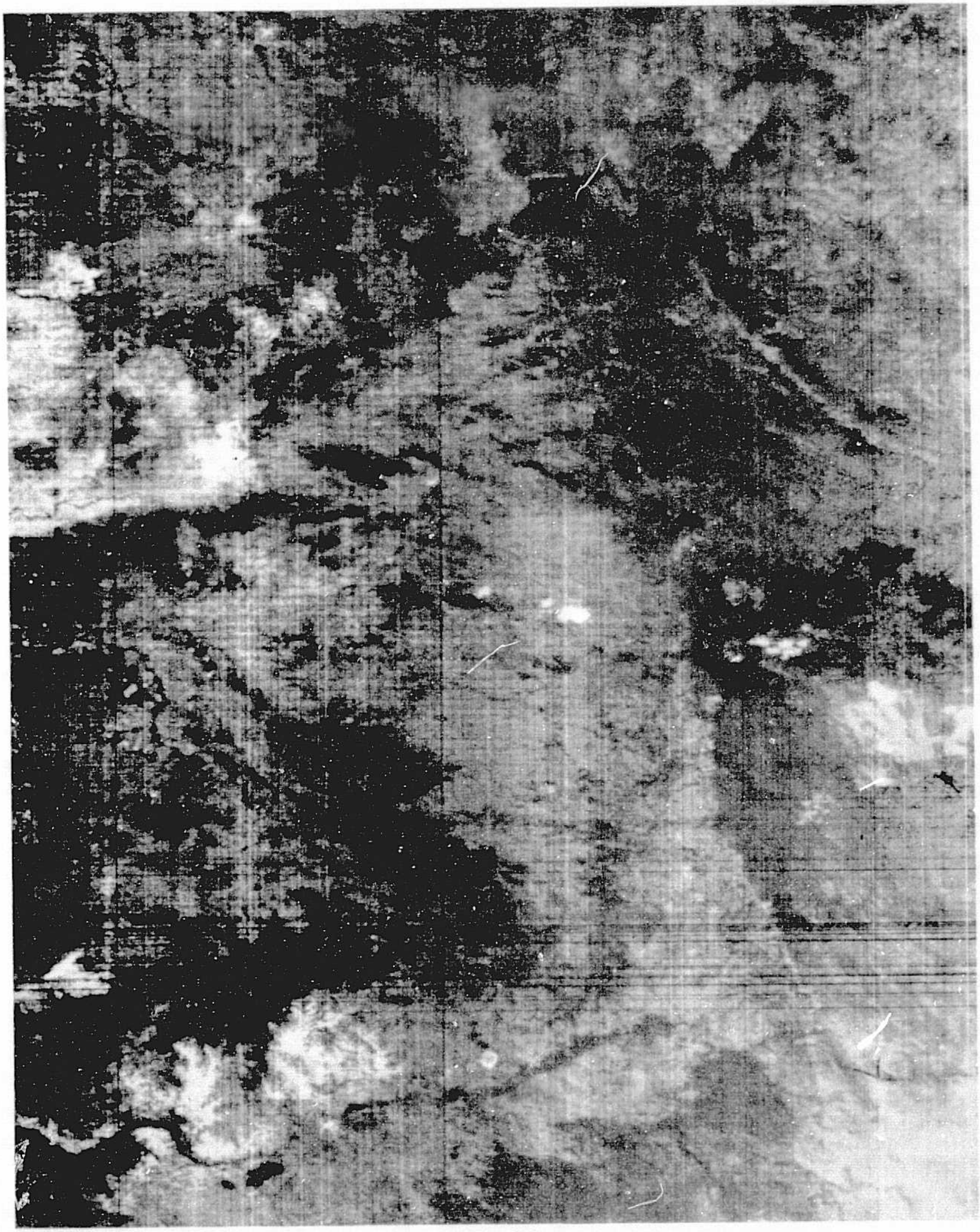


Figure 3.— Photographic enhancement of Landsat image.

ORIGINAL PAGE IS
OF POOR QUALITY

Landsat-type scanners are now available for light aircraft. They can be obtained with additional spectral channels including panchromatic visible and thermal channels such as are found on meteorological satellites. Data from such sensors are processed in the same way as are Landsat data.

3.5 SUMMARY

Results of a brief study of the vegetation and remote sensing of the Tanzanian test site may be summarized in the following way. The vegetation of Tanzania is primarily composed of varying stages of woodland-savannah. Some true grasslands do occur along with some near desert regions and swamps. Very little heavy forest is in evidence. While the vegetation is generally quite monotonous and similar, physiognomic aspects of it lend themselves to the classification methods used in remote sensing.

It appears that widespread use may be made of remote sensing to the mapping of the vegetation of Tanzania. It is not possible to determine what use, if any, the remotely sensed data might have on the efforts to eradicate tsetse flies from Tanzania. Only further field and laboratory work by botanists and entomologists will yield a satisfactory answer to this latter problem.

PRECEDING PAGE BLANK NOT FILMED

4. ZONE DISCRIMINATION

4.1 USE OF ZONE DISCRIMINATION

Although no trials have yet been made, it is probable that the zone discrimination technique of Arp and Phinney (ref. 2) can furnish useful information for tsetse eradication. It is probable that zones produced by this technique can be correlated with ecological zones which coincide with the limits of various species of the tsetse fly. This technique is briefly described below.

Daytime temperatures of the radiating canopy are related to both air and soil temperatures, both of which have a strong effect on vegetation; they also reflect a dynamic relationship between incoming solar radiation and the type of surface in sight of it. Night time temperatures are more controlled by temperature equilibrium, but are strongly affected by subsoil structure, soil moisture, and other factors; they also follow air temperatures more closely. Visible images of the surface allow us to distinguish many zones on the basis of their reflectivity. just as we would in a panchromatic black and white film. In short, all three types of data furnish unique information for discriminating vegetation zones.

The Arp-Phinney discriminator combines these three types of data in a way that distinguishes finite reflectivity-thermal zones, and these largely reflect ecological and vegetation zones. It makes use of standard LARSYS* clustering programs and it can probably be used more directly with supervised classification programs. It has also been applied visually, using the implicit clustering involved in the display of three images using separate primary colors, a simple task for flexible display systems such as the IMAGE 100 processing system.

*Classification system of the Laboratory for Application of Remote Sensing.

4.2 SATELLITE DATA FOR THE DISCRIMINATOR

As used by Arp and Phinney, the zone discriminator needs to be applied to each season. As a practical matter, two or three seasons were sufficient to monitor the changes in vegetation of interest in Mexico. For Tanzania, probably only two sets of images would be necessary, one for summer and one for winter.

The discriminator uses cloud-free composites made from a nearly consecutive series of images. For example, for winter, a cloud-free composite of day infrared images would be made by registering a number of day infrared images to a common map, then picking the highest temperature value for each pixel. Since clouds are normally colder than land surfaces, the composite image is free of clouds wherever land was ever seen. Night infrared images are made in the same way. Visible images are made in the same way, except that the lowest radiance is chosen for each pixel.

Although Arp and Phinney found that two of these images were sufficient for discriminating zones of importance to their project, three such images are preferable. Their studies were usually limited to two because of excessive night cloud cover in parts of Mexico; in some areas there were no cloud-free autumn nights.

The concept of the discriminator is certainly not limited to three images per day; it was merely developed on the basis of the three images conveniently available from the Very High Resolution Radiometer of the ITOS/NOAA satellites which furnish images at local time, 9 a.m. and 9 p.m. It is possible, for example, to use the six images from two seasons in a temporal classification scheme.

There are other potential sources of data for the zone discriminator. In about 1978, the SMS/GOES type satellite of ESA will

be available for use. With it, images from times of day of most interest will be available. For example, if noon images are most useful, or if 10 a.m., 2 p.m., and midnight images contain the most information, those will all be available for the discriminator.

5. EXTENSION OF SEDS TECHNOLOGY

The Screwworm Eradication Data System (SEDS) is a complex system for converting daily information from ITOS/NOAA satellites to surface air temperatures, and interpreting the effect of weather on screwworm populations (ref. 2). Although the system was never used for its intended purpose, it is the first system that can predict surface air temperatures for an entire subcontinental area on a daily basis. It measured daily mean air temperature within 3.5° C when it ceased operation. It was very apparent that precision could be increased to better than 2.5° C with minor changes, and probably better yet with major changes. It produced temperature values for a 4-kilometer grid, and it could could easily have been changed to a 1-kilometer grid.

SEDS is a complex system, with many useful features for diverse applications. This section will probe its potential usefulness to the control of tsetse flies.

5.1 DAILY MEAN AIR TEMPERATURES

The chief data produced by SEDS are a complete grid of surface air temperatures. Seasonal trends in air temperature were known to be important since they controlled the advance and retreat of the screwworm into northern areas and from low to high areas.

There is apparently no such seasonality in tsetse infestations. In addition, the seasonal trends in Tanzania are so small that there is little point to monitoring than on a daily or a weekly basis. Figure 5 shows the trends in mean air temperature for the two climatic zones in Tanzania; the annual range in mean temperatures (on a monthly basis) is only 6° F inland and 8.5° F on the coast. Figure 6 shows that within the SEDS grid the range was much greater except in the small isthmus area; the

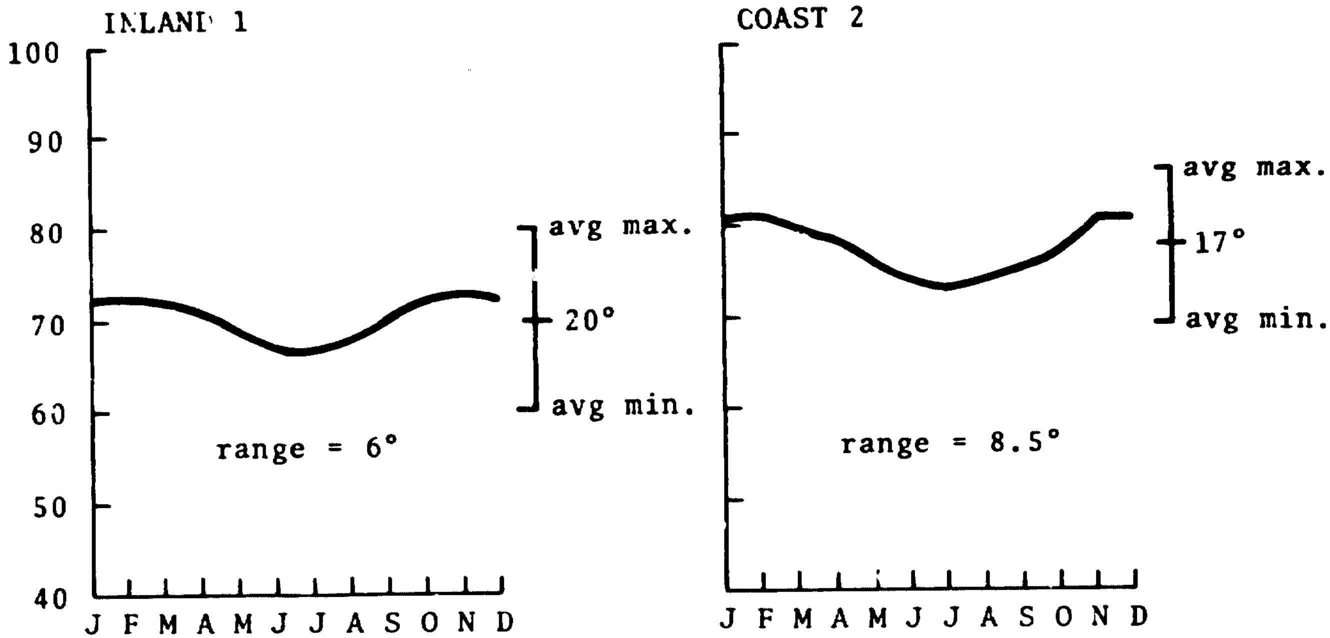


Figure 5.– Mean air temperature for climatological areas of Tanzania.

ORIGINAL PAGE IS
OF POOR QUALITY

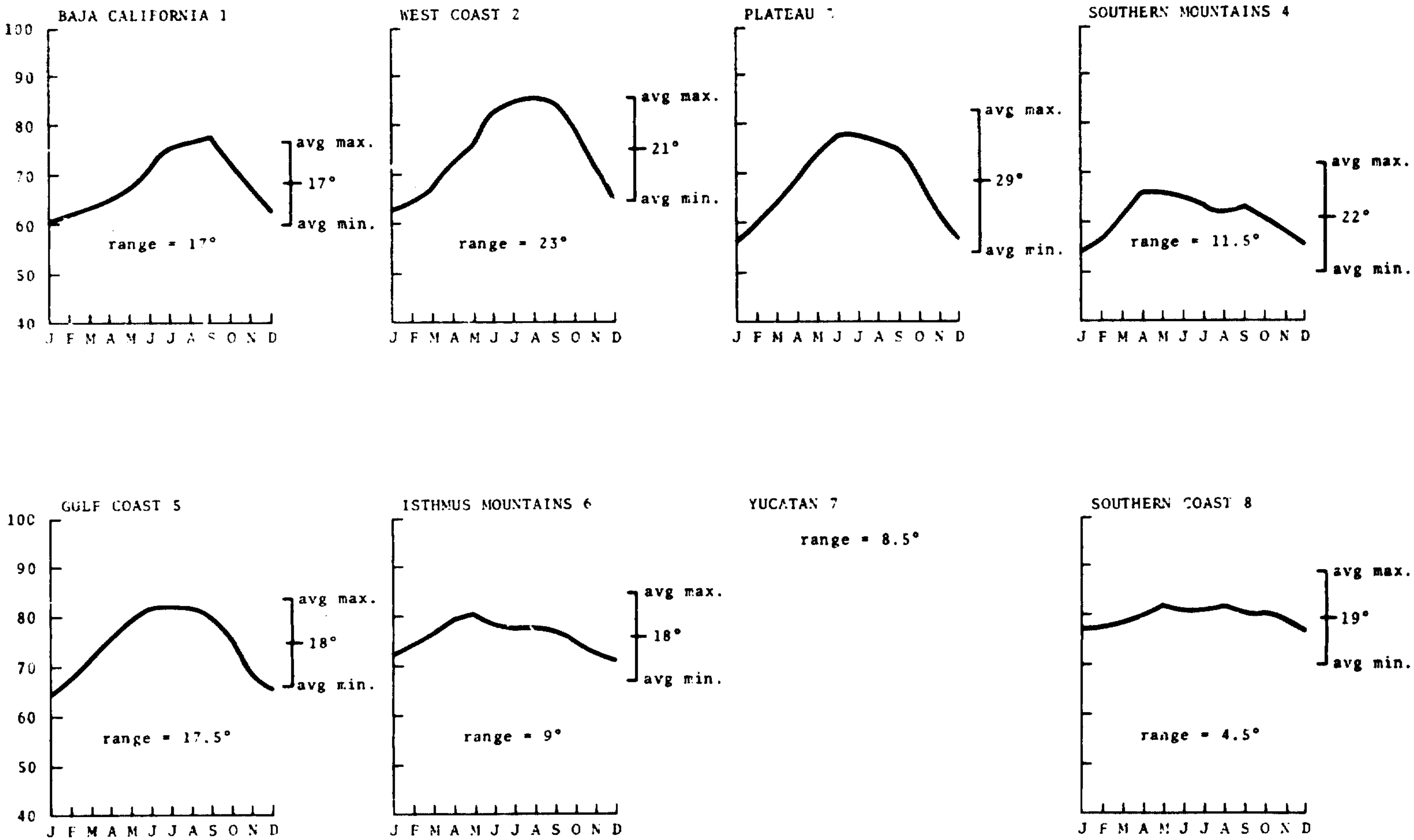


Figure 6.– Mean air temperatures for climatological areas of Mexico.

Yucatan peninsula and the southern coast, both outside the SEDS grid, also have small ranges.

On the other hand, in Tanzania the difference between average maximum and average minimum temperatures (as shown to the side of each curve in these figures) is about the same as in Mexico. This shows that the diurnal variation is about the same as the annual variation of the mean in Mexico; in Tanzania it is twice the annual variation.

The morning overpass of NOAA/ITOS satellites occurs at about 9 a.m., a relatively unstable time in the earth's heating cycles, so that estimated temperatures would not be very precise. Small variations in time from sunrise to time of overpass could cause serious variations. As a result, it would be difficult to monitor the very small seasonal trends. In point of fact, it would probably be more accurate to estimate mean air temperatures from seasonal trends than calculate them from satellite data.

For the same reason, temperature summations, such as degree-day sums or averages, should not be measured from daily data from the NOAA satellites. However, as will be seen below, there are alternative ways of producing these data in a very detailed way which involve satellite technology related to that developed in SEDS.

5.2 EXTENSIONS OF SEDS TECHNOLOGY

There are two innovations in SEDS that are likely to prove useful for the tsetse project. The first, the zone discrimination technique of Phinney and Arp, is discussed in section 4. The other, discussed here, is the extensive use of a temperature model.

5.3 TEMPERATURE MODEL

The ΔT field in SEDS, originated by Boatright, (ref. 3), is a specialized version of the general field of temperature models. In effect, data from surface meteorological stations can be extended to all points of an area around the station by coupling it with a temperature model. The ΔT field of SEDS is an internally generated model which is used only when data are missing; but it is perfectly feasible to use an externally generated model and bypass real-time satellite data.

5.4 TEMPERATURE MEASUREMENTS

Since temperature varies relatively slowly in a predictable way in the humid tropics, a temperature model scheme should be especially valuable. Since the relationship between the temperatures of two areas is stable, the model can be used to obtain quite precise temperature values throughout an area, (ref. 4).

In concept, temperatures from a given ground station are compared with a model. If five degrees must be added to the model then five degrees will be added to the temperature of each pixel in the model. The result is a temperature estimation over a broad area based on measured surface data but extended by the model.

The identical process can be used to extend temperature extremes. It can also be used, probably with great precision, to extend several day averages and degree-day sums.

5.5 MODELS

Satellites intervene in this system only for the data used to prepare temperature models. In essence, high resolution radiometer data, such as VHRR, must be registered and converted to air temperature data. Several images need to be prepared in composite to eliminate cloud contamination of the model.

6. SUMMARY

There is a wide variety of remote sensing information that can be collected for use in tsetse control activities. Its use will depend on the knowledge and imagination of experts in tsetse fly research. Some possible uses, mentioned in this report, include discrimination of vegetation zones, measurement of temperature variables, including temperature summations, discrimination of ecological zones from data collected from space, and fine discrimination of vegetation zones from sensors mounted in aircraft.

7. REFERENCES

1. Giddings, L. E.: *Satellites for Life Sciences.* NASA/JSC (Houston), LEC-7737, JSC-10856, 1976.

2. Arp, A.; Forsberg, F.; Giddings, L.; and Phinney, D.: *Systems Development of the Screwworm Eradication Data System (SEDS) Algorithm.* NASA/JSC (Houston) LEC-7646, JSC-10965, 1976 (STAR: 76N22876*#).

3. *Screwworm Eradication Data System (SEDS), System Software Performance Specification.* NASA/JSC (Houston), JSC-10090, Aeronutronics Ford Corporation, NAS 9-1261, June, 1976.

4. Giddings, L.: *Extension of Surface Data by Use of Meteorological Satellites.* NASA/JSC, LEC-8377, JSC-11139.

APPENDIX A

SPACE PHOTOGRAPHY OF TANZANIA AND ENVIRONS

SPACE PHOTOGRAPHY OF TANZANIA AND ENVIRONS

Area*	Quality†	Identification	Clouds††	Description
		Gemini 4		
O	F	S65-34796	30	SE Sudan, S Ethiopia, Kenya, Uganda, Lake Rudolph (9-34)
O	P	S65-34796	60	SE Sudan, S Ethiopia, Kenya, Uganda, Lake Rudolph (9-33)
		Gemini 5		
TO	P	S65-45570	65	Tanzania, Lake Tanganyika; looking SW to Congo, Zambia (2-24)
TO	P	S65-45571	55	Tanzania, Zambia, Lake Tanganyika; looking SE (2-25)
TO	F	S65-45572	30	Tanzania, Zambia, Malawi, Lake Nyasa; looking S (2-26)
O	P	S65-45573	70	Mozambique Coast; looking S (2-27)
		Gemini 6		
O	U	S65-63225 to S65-63227	90	Comoro Islands; hazy or sunglint (654-656)
TO	U	S65-63228	100	Tanzania, Mozambique Coast, Indian Ocean (C-53)
C	U	S65-63229	80	Tanzania Coast, S of Dar Es Salaam; hazy (C-52)

See footnotes at the end of appendix A, page A-5.

SPACE PHOTOGRAPHY OF TANZANIA AND ENVIRONS - continued

Area*	Quality†	Identification	Clouds††	Description
		Gemini 6, cont.		
C	P	S65-63230	70	Tanzania Coast, Islands of Zanzibar and Pamba (C-51)
T	P	S65-63231	40	Tanzania, Lake Victoria, Speke Gulf; hazy (C-50)
T	P	S65-63232	50	Tanzania, Lake Victoria, Speke Gulf; hazy (C-49)
O	U	S65-63233	90	Uganda, Lake Victoria, Sese Islands (C-48)
		Gemini 7		
O	P	S65-63952	60	Somali, Coast S of Mogadishu (23-39)
O	U	S65-64023		E Coast of Africa; underexposed (25-33)
O	G	S65-64015 to S65-64019	0	Ethiopia, Samali (25-25 to 25-29)
O	G	S65-64020	5	Somali (25-30)
O	G	S65-64021	10	Somali Coast (25-31)

See footnotes at the end of appendix A, page A-5.

SPACE PHOTOGRAPHY OF TANZANIA AND ENVIRONS - continued

Area*	Quality[†]	Identification	Clouds[††]	Description
		Gemini 9		
TO	U	S66-38449	50	Kenya, Tanzania, Uganda, Lake Victoria, Kauidrondo Gulf, Speke Gulf; hazy; oblique, looking SW (B-55)
TO	U	S66-38450	50	Kenya, Tanzania, Uganda, Lake Victoria, Kauirondo Gulf, Speke Gulf; hazy; oblique, looking SW (B-56)
TO	U	S66-38451	30	Tanzania, Kenya, Somali, Indian Ocean Coast; very hazy (B-57)
O	U	S66-38452	90	Somali, Indian Ocean Coast; oblique, looking W (B-58)
O	U	S66-38453	90	Kenya, Somali, Indian Ocean Coast; very hazy; oblique (B-59)
O	U	S66-38454	90	Somali Coast, Indian Ocean (B-60)
O	U	S66-38455	90	Somali Coast, Indian Ocean (B-61)
O	U	S66-38456	90	Somali Coast, Indian Ocean; partial frame (B-62)
		Apollo 6		
O	U	AS6-1045 to AS6-1072	Varied	Mozambique to Madagaskar; not hand-held (mounted in space ship); underexposed

See footnotes at the end of appendix A, page A-5.

SPACE PHOTOGRAPHY OF TANZANIA AND ENVIRONS - continued

Area*	Quality†	Identification	Clouds††	Description
		Apollo 7		
	P	AS7-1780	80	Kenya, Somali Coast; hazy, underexposed
C	U	AS7-1781	90	Tanzania, Mafia Island, Mafia Channel; hazy, underexposed
T	P	AS7-1861	60	Tanzania, Burundi, Lake Tanganyika; underexposed
O	U	AS7-1883	90	Kenya Coastline, Formosa Bay, Tana River, Seya Channel; underexposed
	U	AS7-1884	90	Somali, Kenya Coastline, S of Chismara; dark (underexposed)
		Apollo 9		
O	F	AS9-3116	20	Somali, Mogadiscio, Scebeli River, Arabian Sea
O	F	AS9-3117	20	Somali, looking NE to DiHafun Peninsula, Arabian Sea

See footnotes at the end of appendix A, page A-5.

SPACE PHOTOGRAPHY OF TANZANIA AND ENVIRONS - concluded

Area*	Quality†	Identification	Clouds††	Description
		Skylab Handheld 70 mm		
C	U	SL2-5-372	90	Zambia, Malawi, Tanzania, Lake Nyasa; oblique
	U	SL4-137-03694	90	Tanzania, Zaire, Burundi, Lakes Tanganyika and Kiva; overexposed, oblique
	F	SL4-137-03716	60	Tanzania, Tabora; haze
	U	SL4-138-03733	90	Tanzania; haze
	P	SL4-138-3735	80	Tanzania, Kenya, Lake Victoria, Speke Gulf, Serengeti Plain; oblique
		SL4-141-4412		Kenya, SE of Lake Rudolph; volcanic area
T	P	SL4-142-4495	60	Tanzania, at 5° S Lat., 33° E Long.

* Z = Zanzibar; C = Coast of Tanzania near Zanzibar
T = Other parts of Tanzania
O = Countries surrounding Tanzania

† E = excellent; G = good; F = fair; P = poor

†† Percent of land area covered by clouds

NASA-JSC